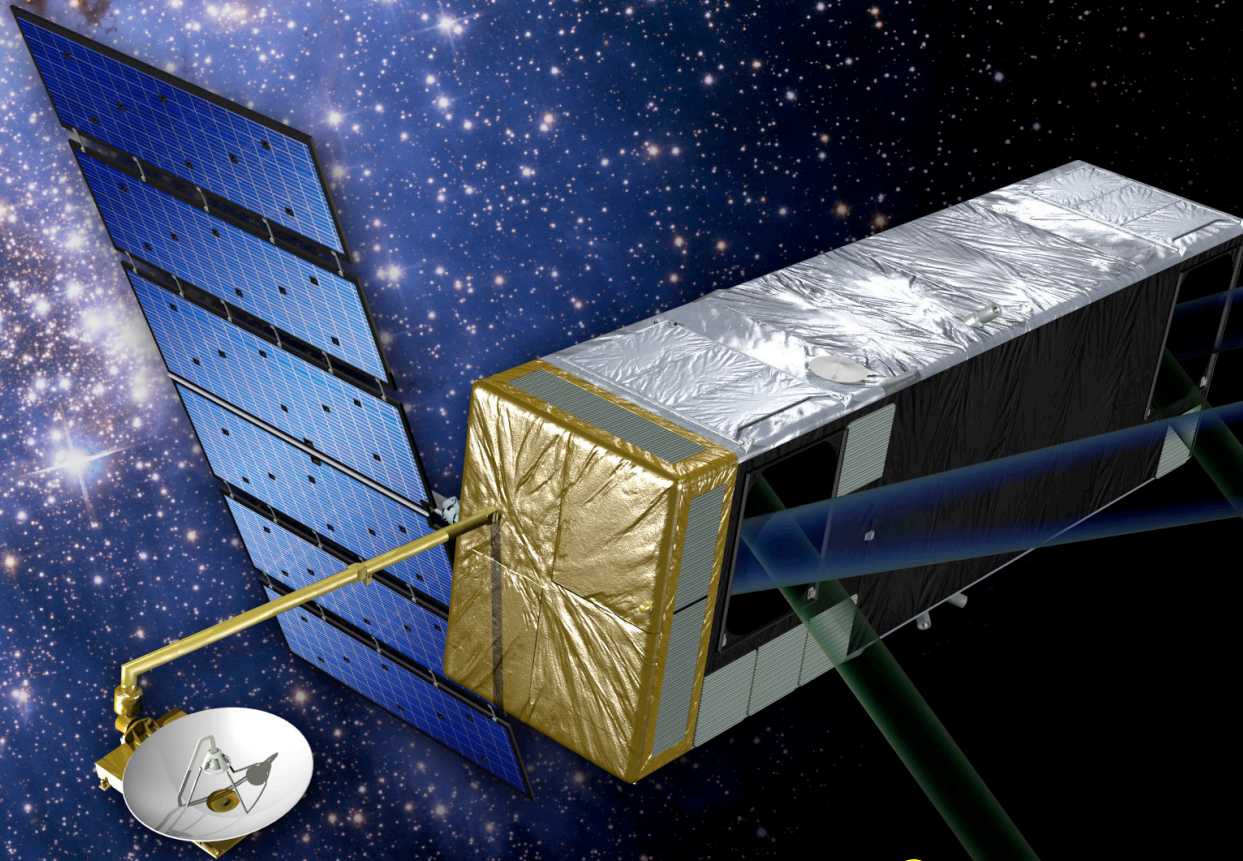


Taking the Measure of the Universe...



**Space  
Interferometry  
Mission**

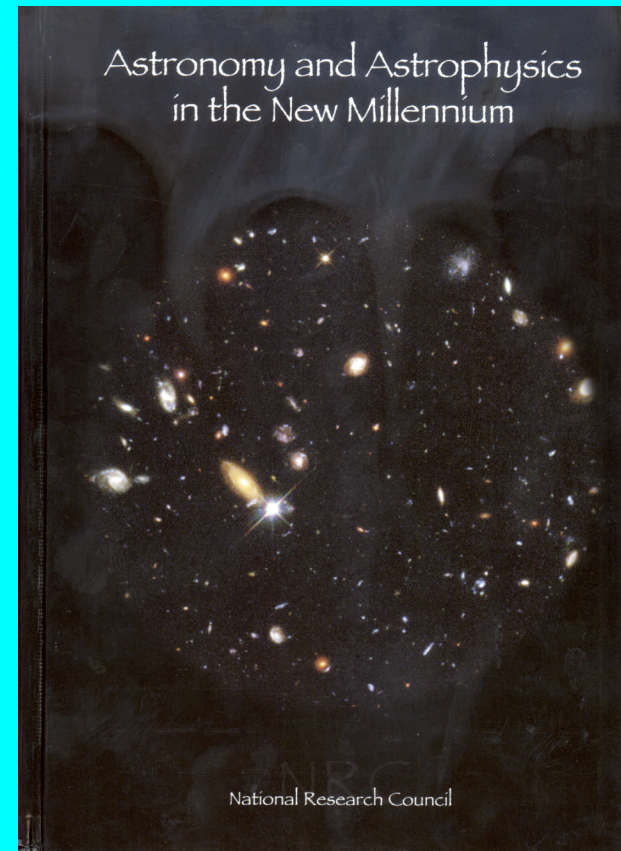
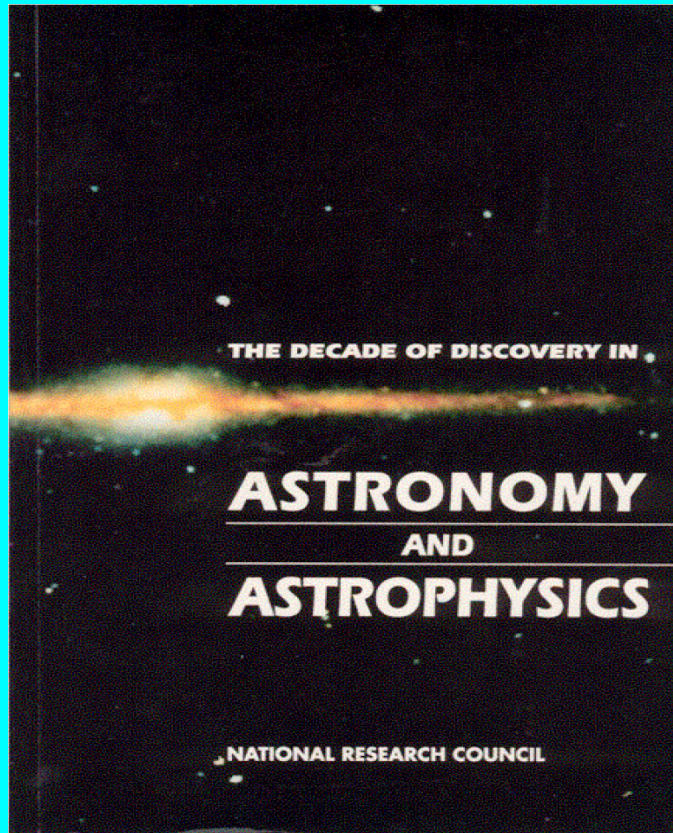
*“You understand something truly only when you can measure it precisely.”* Lord Kelvin

- Measure precise distances -- the basis to physics of stars and physics of the Universe
- Determine the mass makeup of our Galaxy and the Local Group
- Detect earth mass planets in the habitable zone of nearby Sun-like stars
- Direct insight into the formation & diversity of other planetary systems through orbit measurements

*Confucius says “One excellent measurement is better than many mediocre measurements.”*



## 1990 & 2000 Decadal Reviews Endorse SIM



“...emphasized the dual capability of SIM, noting that this capability would enable “...*both... detecting planets and ... mapping the structure of the Milky Way and other nearby galaxies.*”

# “No Distance, no physics”

The history of astronomy is entwined with the determination of reliable distances

- Size of the Galaxy
- Size of the Local Group
- Size of the Universe
- Origin of Gamma-ray bursts
- SIM is a “distance measuring” machine
  - Poorly understood objects
  - New classes of objects, transients (e.g. PanSTARRS, LSST)
  - Rare objects (Neutron Star Systems, Black Hole Systems)
- A “Distance Determination” Key Project will constitute a powerful legacy to astronomy

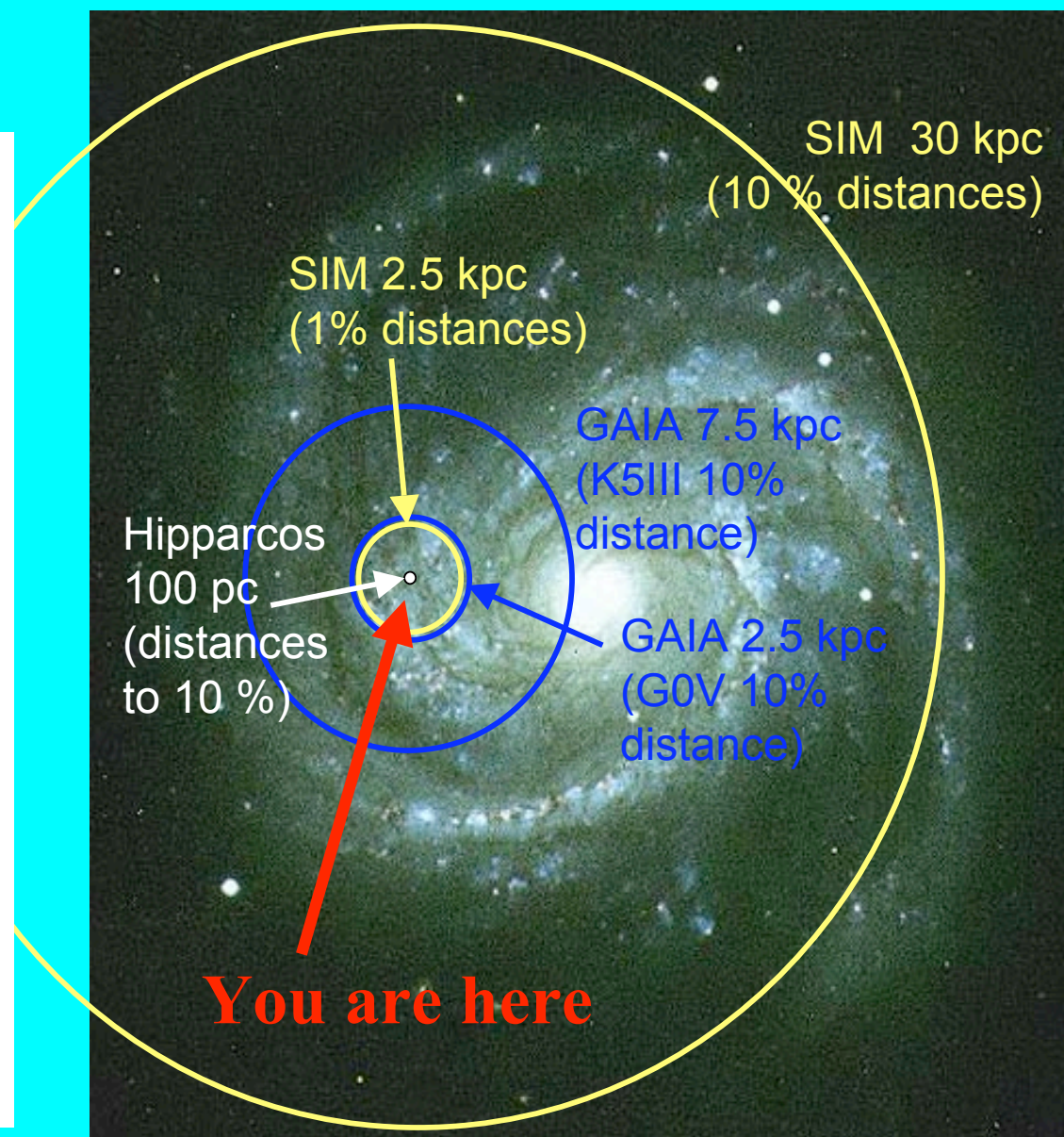


# SIM & Gaia: Synergy

- Gaia is the Survey Machine
  - E.g. the Palomar Sky Survey
  - E.g. Sloan Digital Sky Survey
- SIM is the Observatory
  - E.g. Keck Observatory
  - Hubble Space Telescope

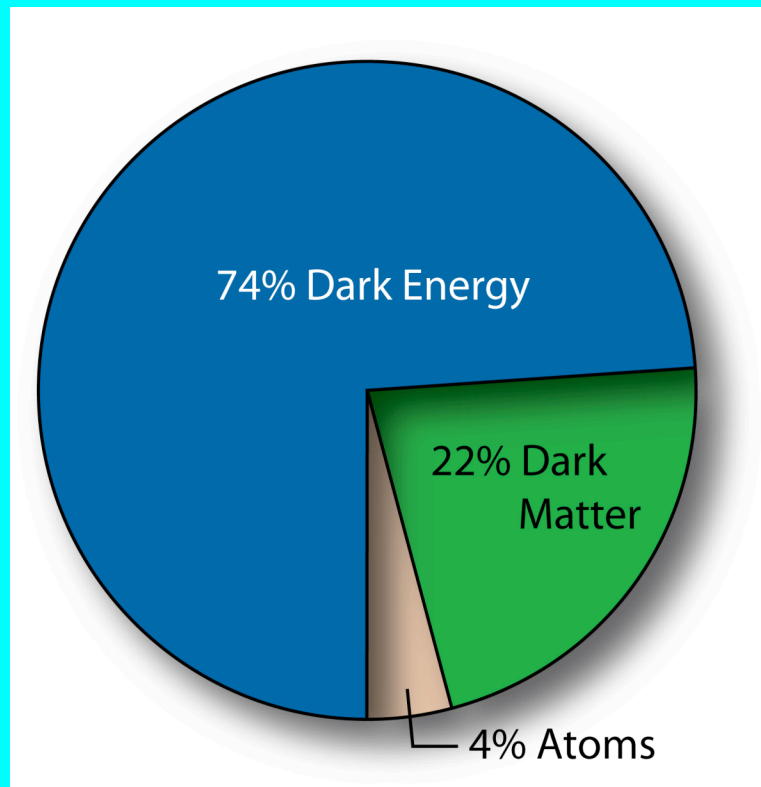
# SIM's Reach: the Galaxy

- Extreme astrometric precision
  - 4  $\mu$ as
  - 4  $\mu$ as/yr
  - 1  $\mu$ as differential
- Ability to observe faint targets
  - $V < \sim 20$
- Flexible scheduling





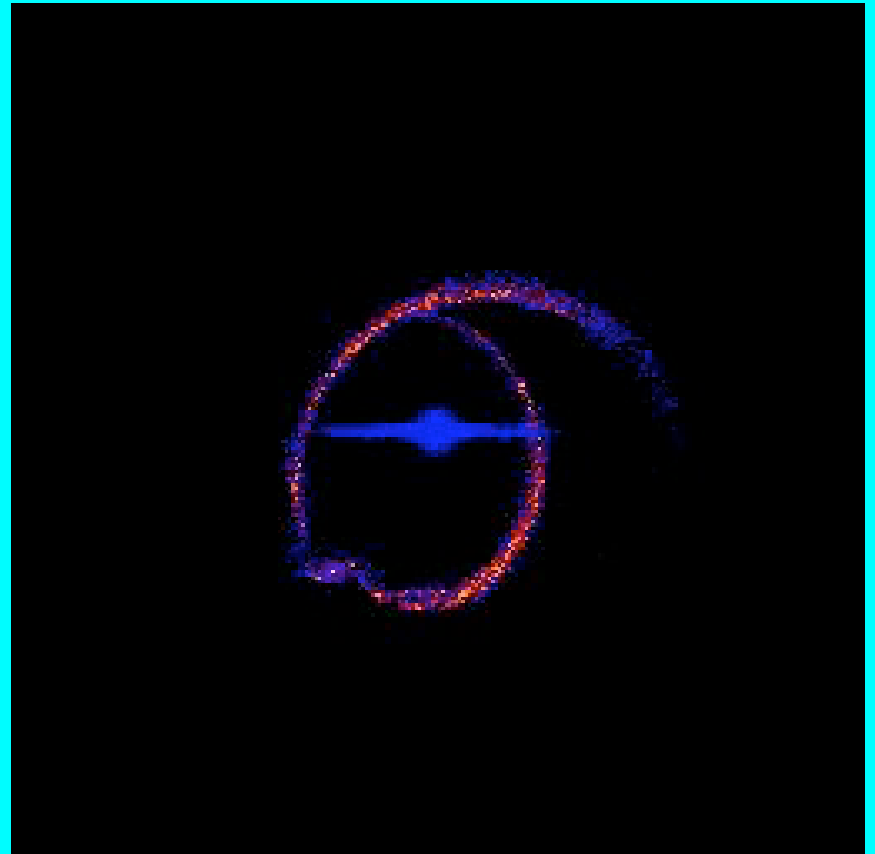
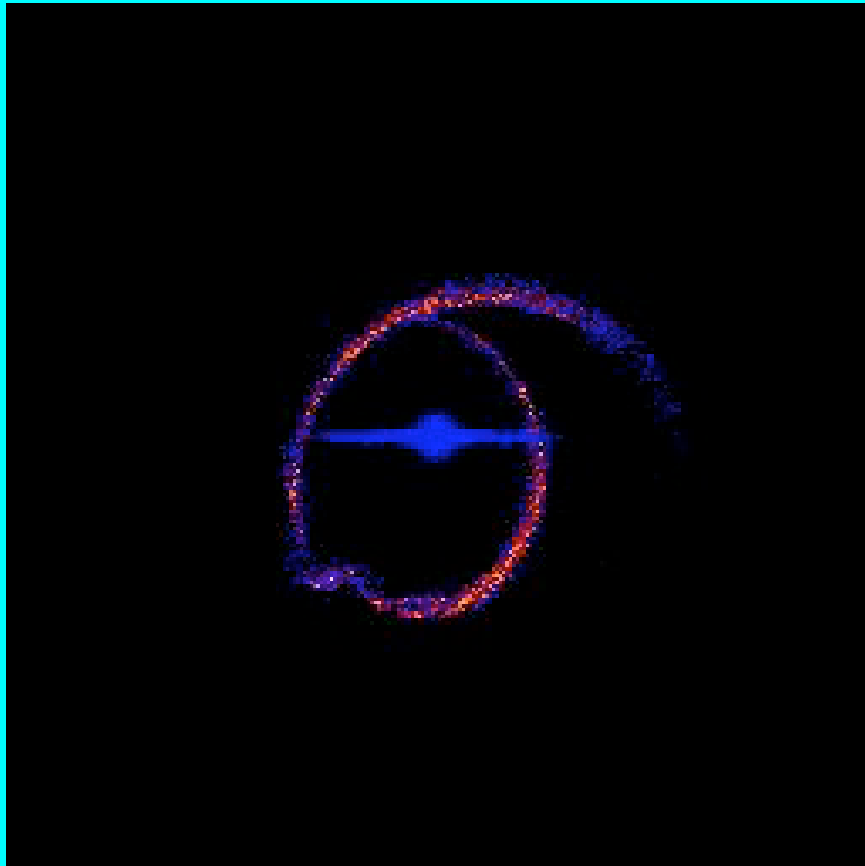
# A COSMIC PROBLEM: The Ghost of Hubble (7% is not good enough)



Precision cosmology is limited by precision (and accuracy) of Hubble's constant

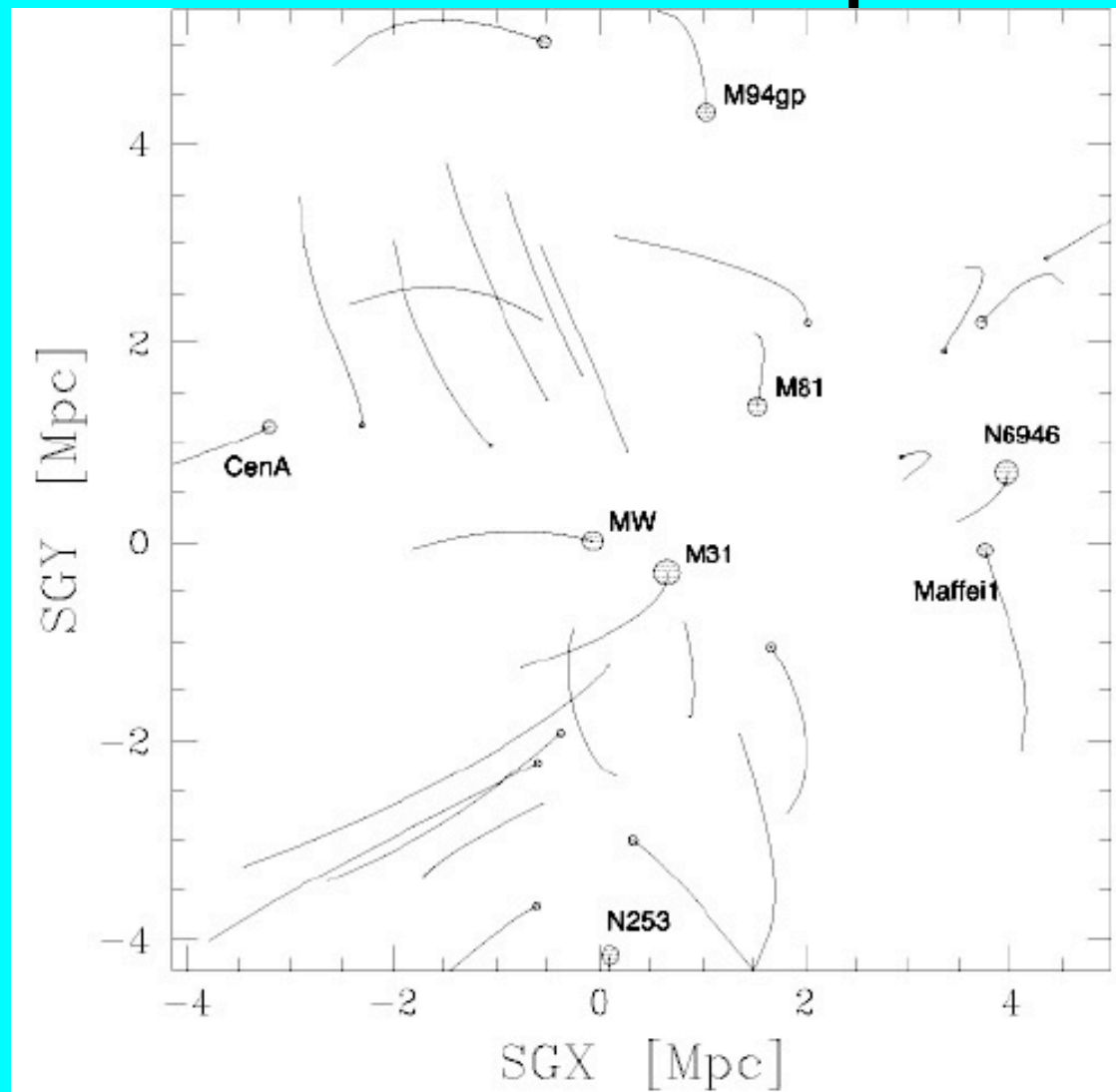
- SIM can undertake a thorough calibration of Galactic Cepheids
- SIM can measure the distances to M31 and M33 (rotational parallax)

# Shape of our Galaxy



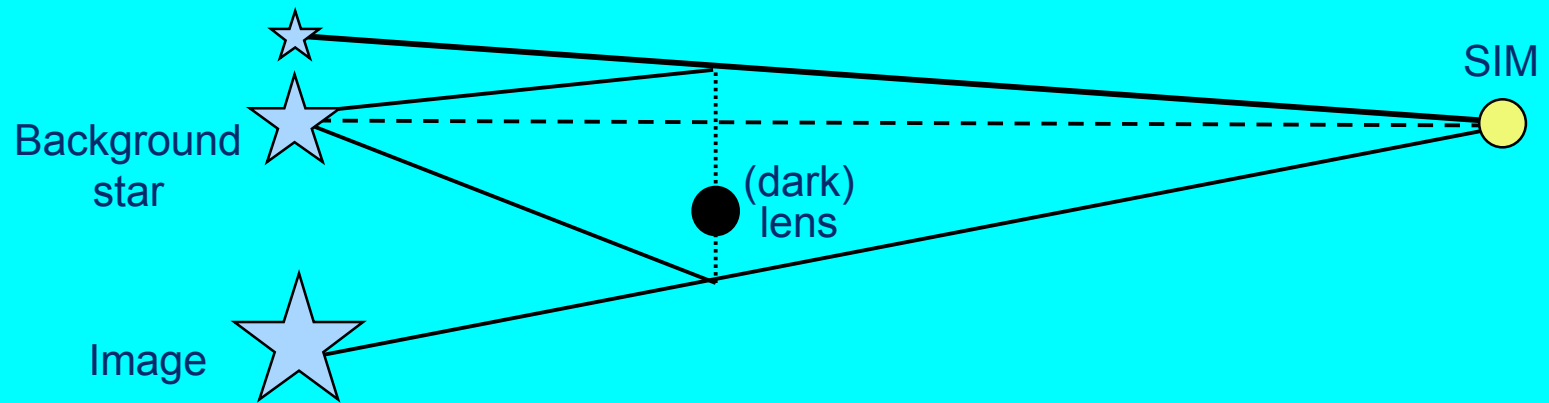


# Matter Distribution of the Local Group



**Simulated 1 Gyr trajectories of our neighbours**

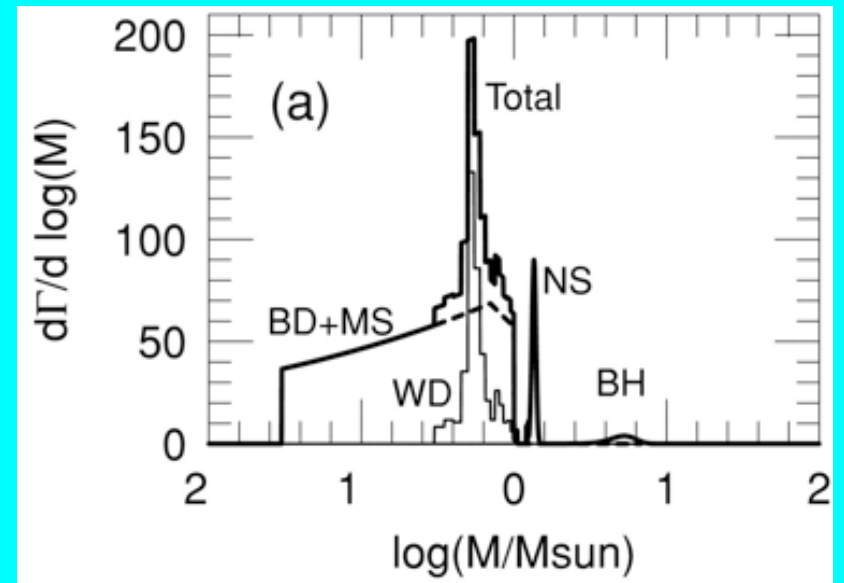
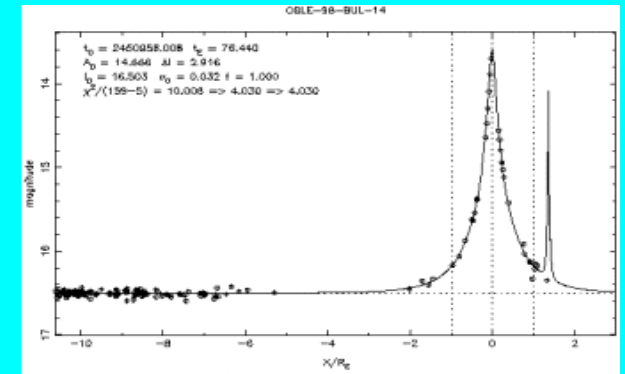
# Using Gravitational Lenses to Probe 'Dark Matter'



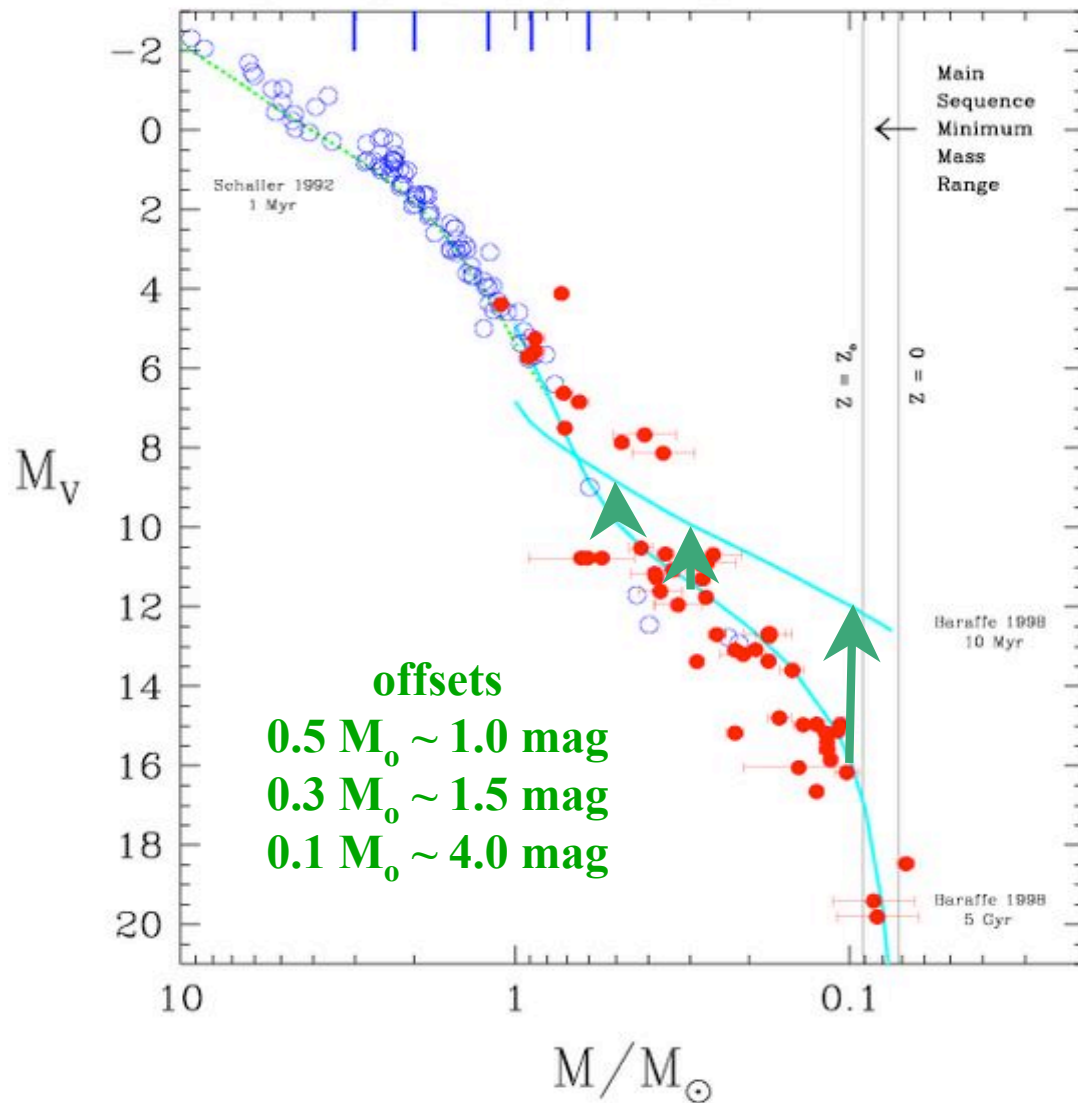


# Using Gravitational Lenses to Probe 'Dark Matter'

- Events are detected by
  - Brightness enhancement (~days)
  - ground based
  - Astrometric perturbation (~weeks to months) – SIM,  $\sim 100 \mu\text{as}$
- Symmetry of astrometric track 'broken' by Earth orbit motion due to lens parallax
  - Hence: distance to lens
- Derive:
  - mass, distance, and velocity of the lensing object
  - Mass function in the Galactic Bulge of (mostly) dark remnants



# Stellar masses - big and small



- O/B stars
  - quick evolution = lots of action
  - distances generally beyond GAIA reach
  - answers ... what is the biggest star?
- Red dwarfs
  - age tells all
  - faint for GAIA, but not too faint for SIM
    - subdwarfs for metallicity axis
    - substellar is new territory
  - answers ... what is the smallest star?

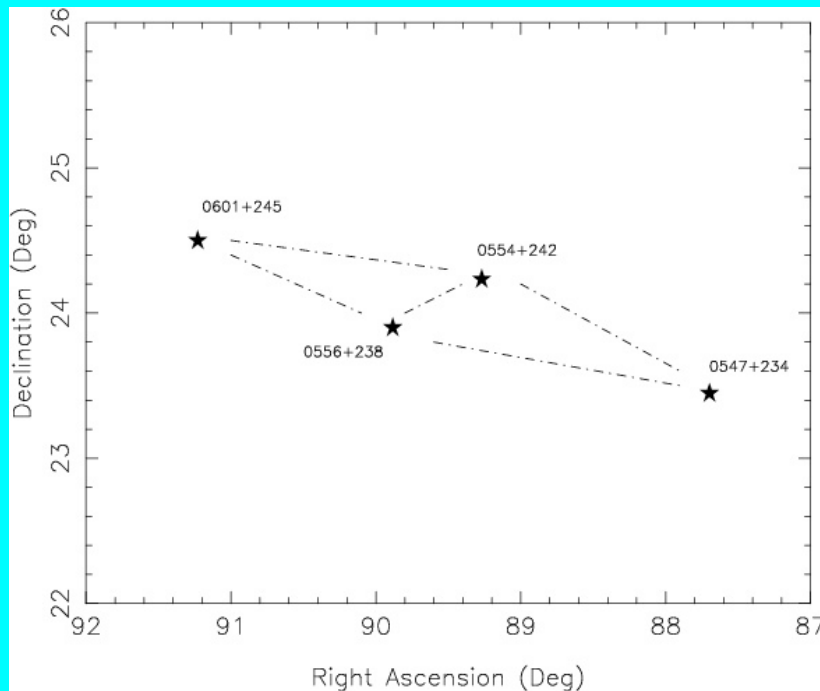


# Fundamental Astronomy & Fundamental Physics

- SIM has the ability to determine masses of neutron stars and black holes
  - Stellar black holes .. Lab for strong gravity and lab for jet formation
    - Determine the mass scale for QPOs
  - Neutron stars ... Lab for dense matter (e.g. Vela X-1 and equation of state)

# Quasar Reference Frame: SIM & ICRF

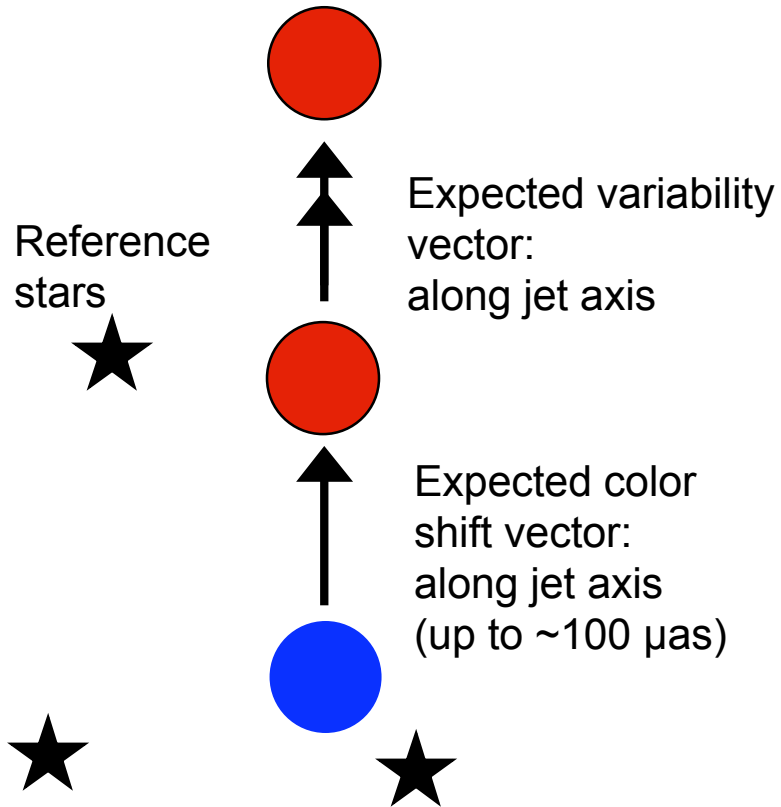
- SIM will observe 50-100 quasars to define an inertial frame to  $2 \mu\text{as/yr}$
- Radio-loud (ICRF) quasars will provide registration to the ICRF to  $< 20 \mu\text{as}$



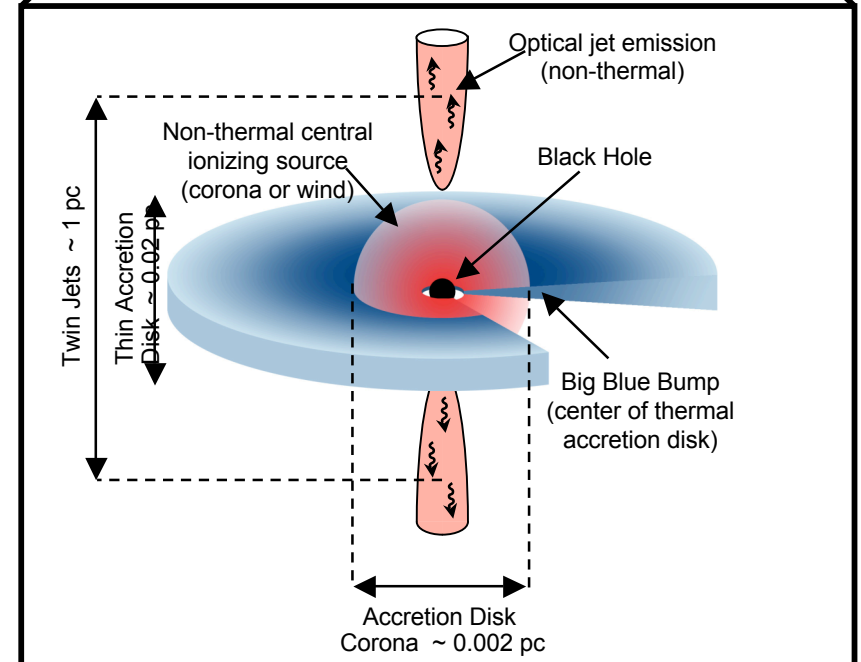
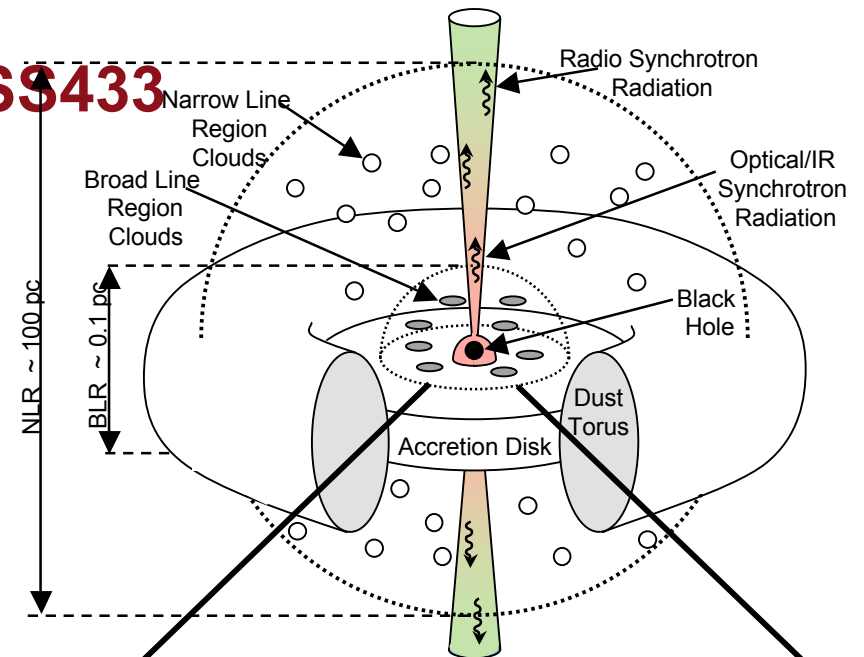
**Relative quasar positions on the sky**

# Launching of Jets: Quasars & S5433

## Radio-loud AGN



## Radio-quiet AGN

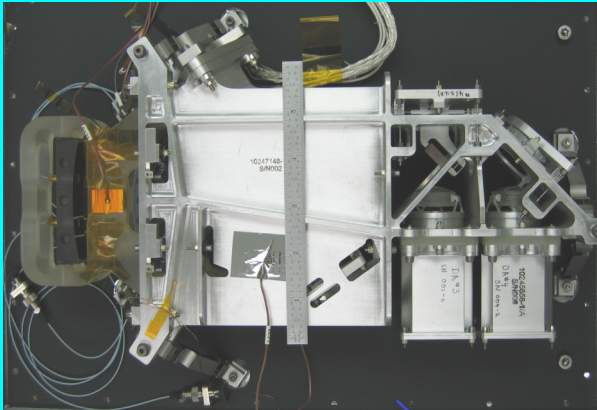




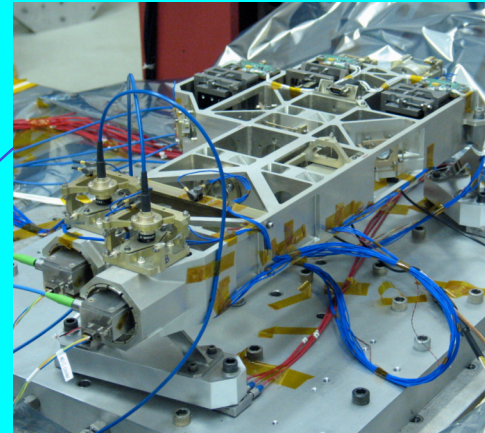
# Emerging Applications

- Realize the full potential of Kepler Mission
  - Radius of target stars
  - Precision Mass-radius relation for white dwarfs
- Physics of newly discovered classes of objects and transients
- High Velocity Stars as probes of our Galactic Halo
- Determine whether CDM is cusped or not

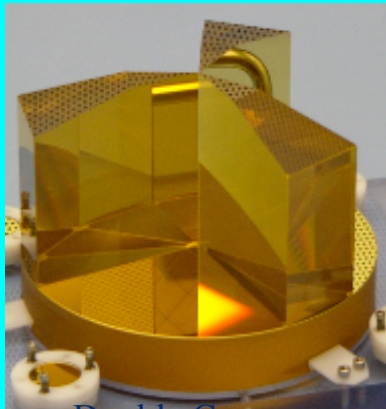
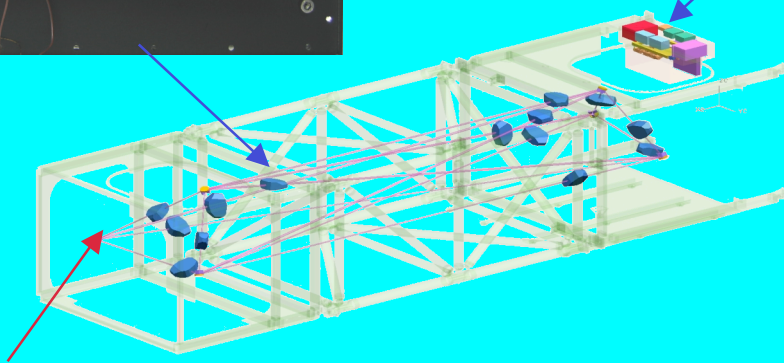
2005: We were ready!



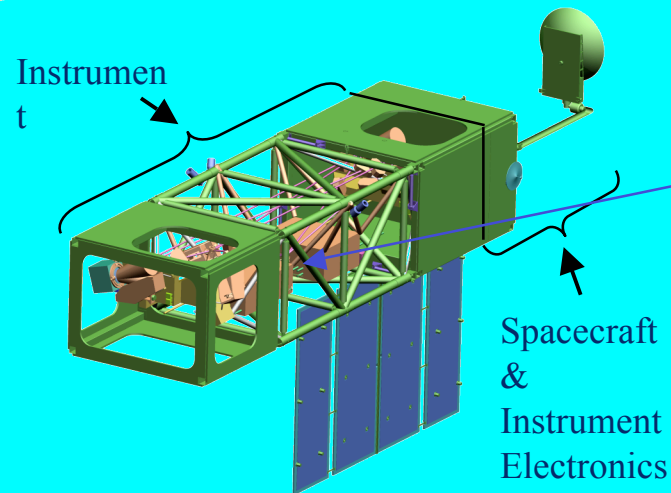
External  
Metrology  
Launcher



Metrology  
Source

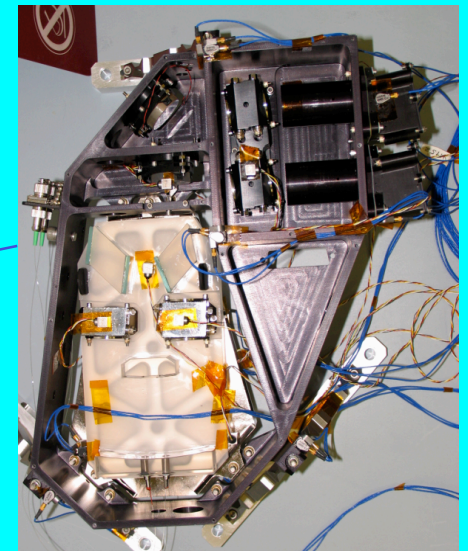


Double Corner  
Cube



Instrumen  
t

Spacecraft  
&  
Instrument  
Electronics



Internal Metrology  
Launcher

Nanometer Control & Picometer Knowledge: Flight Ready Hardware

**THE END**